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# Small satellites and the DARPA/Air Force FALCON program

David J. Weeks[a,*], Steven H. Walker[b], Robert L. Sackheim[c]

[a] *Exploration and Development Office, National Aeronautics and Space Administration, Marshall Space Flight Center, Alabama, USA*
[b] *FALCON Program, Defense Advanced Research Projects Agency, Arlington, VA, USA*
[c] *National Aeronautics and Space Administration, Marshall Space Flight Center, Alabama, USA*

**Abstract**

The FALCON program is a technology demonstration effort with three major components: a Small Launch Vehicle (SLV), a Hypersonic Technology Vehicle (HTV), and a Hypersonic Cruise Vehicle (HCV). Sponsored by the Defense Advanced Research Projects Agency (DARPA) and executed jointly by the United States Air Force and DARPA with NASA participation, the objectives are to develop and demonstrate technologies that will enable both near-term and far-term capability to execute time-critical, global reach missions. The focus of this paper is on the SLV as it relates to small satellites and the implications of lower cost to orbit for small satellites. The target recurring cost for placing 1000 pounds payloads into a circular reference orbit of 28.5° at 100 nautical miles is $5,000,000 per launch. This includes range costs but not the payload or payload integration costs. In addition to the nominal 1000 pounds to low earth orbit (LEO), FALCON is seeking delivery of a range of orbital payloads from 220 to 2200 pounds to the reference orbit. Once placed on 'alert' status, the SLV must be capable of launch within 24 h.
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## 1. Introduction

In 2003, the Defense Advanced Research Projects Agency (DARPA) announced a new joint program with the United States Air Force called FALCON. The program goal is to develop and validate, in-flight, the technologies that will demonstrate affordable and responsive spacelift as well as enable the capability to promptly execute time-critical global reach missions. The program seeks a common set of technologies that can be evolved to provide circa 2010 responsive global reach capability from the continental United States while enabling future development of a reusable Hypersonic Cruise Vehicle (HCV) circa 2025. These technologies will be advanced in their technology readiness levels to flight readiness and then integrated into a system design and flown in a series of flight tests [1].

While the global reach capability focuses on the Hypersonic Technology Vehicle (HTV) and the HCV, a low-cost responsive Small Launch Vehicle (SLV) is needed to launch and carry the HTV to the proper release conditions as well as to provide responsive spacelift. The HTV will be an unpowered yet maneuverable hypersonic glide vehicle. This paper

* Corresponding author.
*E-mail addresses:* dave.weeks@nasa.gov (D.J. Weeks), swalker@darpa.mil (S.H. Walker), bob.sackheim@nasa.gov (R.L. Sackheim).

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will focus on the SLV and specifically the spacelift mission for small satellites.

A Phase I solicitation for concept designs was released in May of 2003 for a SLV that could insert a payload into low earth orbit (LEO), or release a suborbital HTV. Twenty-four proposals were submitted by the industry in response. In December of that year, nine contracts were initiated for 6-month studies to Air Launch LLC, Andrews Space, Exquadrum, KT Engineering, Lockheed Martin, Microcosm, Orbital Science, Schafer, and SpaceX.

In May of 2004, DARPA released a solicitation for Phase 2 SLV activities to include detailed vehicle design, development, test, and flight. A full and open competition was conducted with proposals received by the nine Task 1 contractors plus several other aerospace firms. Phase 2 selections resulted in four contractor awards in September 2004: AirLaunch LLC, Lockheed Martin Michoud Operations, Microcosm, and SpaceX. The Phase 2 period of performance is 36 months, culminating in a demonstration spacelift flight.

## 2. Spacelift requirements

The SLV must be able to launch a small satellite or other payload weighing approximately 1000 pounds to a Reference Orbit which is defined as a circular, 100 nautical miles altitude, due east, launched from 28.5° north latitude. A program desire is to demonstrate flexibility in placing payloads ranging from 220 pounds to 2200 pounds into the same Reference Orbit. An orbital insertion accuracy of plus/minus 13.5 nautical miles must be achieved. Each launch should have a recurring cost of no more than 5 million dollars (US in CY03$), including range costs but excluding the costs of the payload and payload integration. The cost basis for the recurring cost objective is twenty launches per year for 10 years. Ideally, the vehicle used for spacelift could also be used with few modifications for CAV launches.

## 3. Phase 1 results

The Phase I concepts involved an assortment of air launch and ground launch systems with solid, liquid, and hybrid propulsion systems. Liquid propulsion systems included pressure- and pump-fed systems. Air launch enables mission flexibility with respect to the typical launch ranges, but is limited in evolutionary growth potential. Ground launch must deal with weather conditions and azimuth limitations imposed by the launch site location (Fig. 1).

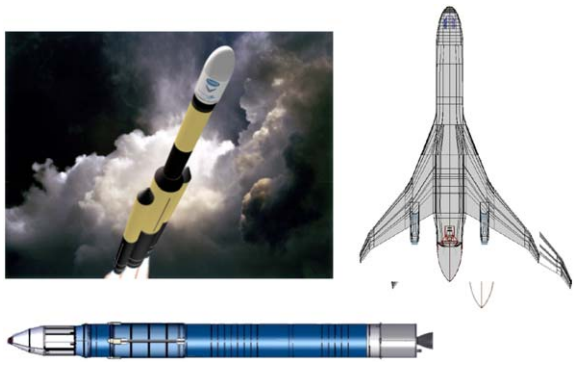

Fig. 1. Representative Phase I concepts.

Each conceptual design had associated trade studies in balancing affordable cost objectives with sufficient vehicle performance and operational responsiveness. Contractors were urged to interact directly with various launch ranges in the United States to understand range requirements and to drive down range costs for future launch vehicles. The driver for each design was the low recurring cost per launch goal of 5 million dollars or less. Vehicle concepts ranged from two staged vehicles with less than 75 ft height to well over 100 ft and 1 million pounds gross lift off weight (GLOW). Design emphases included innovative practices for lowering manufacturing and vehicle assembly costs, incorporating new technology to solve classic vehicle cost and reliability issues, and using existing hardware in new ways. A number of concepts also included streamlined range operations, encapsulated payloads and/or vehicle scalability for larger payloads in the future.

## 4. Phase II beginnings and schedule

Fig. 2 shows the program schedule, indicating that the SLV space lift demonstration launch will be conducted no later than FY07. It is conceivable that a SLV